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AFHRL-TR-74-43

AIR FORCE

HUMAN RESOURCES

ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING (ASUPT) FACILITY UTILIZATION PLAN

By

William V. Hagin
James F. Smith

FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224

June 1974
Interim Report for period March 1972 – March 1974

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LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This technical report has been reviewed and is approved.

WILLIAM V. HAGIN, Technical Director
Flying Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

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The capabilities of a flight simulation research facility located at Williams AFB, AZ are described. Research philosophy to be applied is discussed. Long range and short range objectives are identified. A time phased plan for long range research accomplishment is described. In addition, some examples of near term research efforts which will be conducted during periods when the total system is not available are described in some detail. These projects address immediate simulator users's needs.

PREFACE

This planning effort was completed under Project 1123, USAF Flying Training Development; Task 112303, The Exploitation of Simulation in Flying Training. The major portion of research equipment is being procured under Project 1192, Advanced Simulation in Undergraduate Pilot Training.

This technical report supersedes AFHRL/FT-TRM-18, For Official Use Only.

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ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING (ASUPT) FACILITY UTILIZATION

I. BACKGROUND

In 1967, the Director of Defense Research and Engineering (Reference Memorandum for Assistant Secretary of the Army, Assistant Secretary of the Navy, Assistant Secretary of the Air Force, 2 Sep 65, Subject: Education and Training Research and Development.) established a program, Innovations in Training and Education (INNOVATE), to investigate the application of recently developed modern training techniques to Air Force training programs. The overall objectives of INNOVATE were to: transition new training and educational technology to Air Force operational capabilities; evaluate the applicability of education and training innovations to Air Force problems; experimentally test alternative training systems; and demonstrate significant changes in educational and training concepts, approaches, techniques, and media devices.

ASUPT was a task area within Project INNOVATE. The objective was to design, develop, and utilize a state-of-the-art advanced simulation system for investigating the role of simulation in pilot training. Specific goals were to: enhance pilot training within the Air Force through the application of recent technological advances in simulation (The importance of this objective cannot be over-emphasized. While the research will have obvious implications for Undergraduate Pilot Training, nearly all results will have impact on *all other* aspects of pilot training in which visual and motion cuing are important.); determine design characteristics of future generation ground training equipment and simulators for Undergraduate Pilot Training (UPT); and demonstrate the maximum effective utilization of simulators in UPT.

To carry out the ASUPT objectives, the Air Force Human Resources Laboratory activated the Flying Training Division (AFHRL/FT) at Williams AFB, AZ in July 1969 with the broad mission to "Improve Air Force Flying Training." The Williams facility has grown to include two T-40 trainers, one T-4G equipped with an Electronic Perspective Transformation (EPT) visual, a part task formation flight trainer (FFT), and a computer controlled data acquisition and control system for each device (descriptions provided in Appendix A).

These equipments have already been used to address some of the ASUPT goals: the T-40s have been used in studies of instrument skill acquisition and candidate screening; studies with the T-4G have proved the effectiveness of the EPT as a low-cost visual for learning contact airwork and landing skills, and have shown the power of innovative instructional methods; and the FFT has been demonstrated to be an effective part-task trainer for formation flying.

The ASUPT hardware will be available soon: as a limited non-visual device by June 1974, and as a full visual simulator by November 1974. Much software will have to be generated in-house for it to be research-ready for use with student pilots at that time.

II. PHILOSOPHY OF ASUPT RESEARCH

The ASUPT research equipment provides a wide range of capabilities not heretofore provided in any one simulator (description in Appendix A). These extensive capabilities make possible a variety of research approaches to achieving the objectives of ASUPT. To select the most feasible approach several major factors must be considered: availability of research personnel and subjects; priority of research in terms of cost-effectiveness of anticipated results; manageability of the programs; availability of aircraft hours for use in criteria determination; and applicability of intermediate projects to long-range programs. From these and other related factors, it was determined that there were essentially two possible approaches to utilizing the ASUPT. One approach would involve the simulated fabrication of a device with specifically defined capabilities whose effectiveness could then be evaluated in various training situations. In effect, this amounts to the simulation of subjectively pre-determined simulator configurations. An example might be a device with T-37 performance characteristics, a three DOF motion system, a 50° x 30° visual scene, performance recording equipment, and a conventional instructor station. Obviously, with the flexibility inherent in ASUPT, the number of such designs is unlimited. A second approach would be to examine components of simulators and, through an iterative process, define an optimized simulator training system.

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More specifically, individual hardware and software components would be examined in terms of how variations in their capabilities affect training. Then, in successively more complex combinations of these components, it would be determined how components interact to become an optimum system.

The apparent advantage of the first approach is the immediacy of the research results and the resulting ability to impact procurement of simulators at the earliest possible time. Disadvantages are that: (a) simulation systems procured in this manner may not be optimum; (b) the full capabilities of the ASUPT simulation facility would not be exploited; and (c) it may not be possible to generalize from a given device in a given situation to a different device in a different situation. The systematic nature of the second approach has the advantage of providing knowledge and specific recommendations as to the most effective simulator devices within, or perhaps beyond, the state-of-the-art. Its disadvantage lies in the additional lead-time required to execute the more rigorous research efforts.

In order to best meet the broad needs of the Air Force goals of Air Training Command (ATC), AFHRL/FT developed a two-phase program with the "good" features of both. The first phase has involved research and testing of off-the-shelf or shortlead time items such as the FFT, T-40 and T-4G/EPT (1970–1974) for intermediate study of operational training problems while awaiting the 1975–1980 availability of ASUPT. Application of the results of these study efforts are already reflected in ATC planning: (a) the FFT is being proposed as an operational UPT part-task trainer for formation; (b) training methods developed in evaluation of the T-4G are being tested with a complete class prior to being adopted ATC-wide; and (c) the T-4G with EPT supports their plans for IPIS simulators using an EPT visual.

In the second phase, beginning in Spring 1975, ASUPT capabilities will be utilized as the principle research capability with devices such as T-40 and T-4G evolving into supporting roles. ASUPT studies will adhere closely to a philosophy giving priority to investigations having Air Force-wide implications as well as supporting UPT simulator developments. Basically, there are four areas or categories of research interest: (a) study of the basic components of simulation; (b) examination of the interactions of those components; (c) experimental investigation of candidate simulator devices, and their substitutability for aircraft training; and lastly, (d) development of pilot training syllabi which incorporate the optimum mix of simulator and aircraft training.

Category A studies form the foundation of the research and will include examination of each major independent variable of simulation. The objective is to gather knowledge on the basic components of simulation. These components have been divided into two major classes, *hardware design* and *training methods*. Hardware components consist of the motion, visual, aural, and computer systems which make up the physical parts of the simulator. Training components such as automatic demonstration, variations in task difficulty and sequencing, enhancement of feedback, and malfunction insertion are the intangible aspects of simulation which govern its use. The interdependence of these two classes of components is apparent. Effects of hardware cannot be studied without interaction involving training; nor can training be studied without interactions involving hardware. However, by manipulating only one type of variable at a time, the interactive effect can be controlled; e.g., fixed training methods will be employed while studying a hardware variable, and fixed hardware configurations will be used when studying a training variable.

The general approach to *hardware design* and *training methods* research will be a two-step process. The first part will be directed at establishing the kinds of component configurations to be examined, and the second part will consist of the systematic investigation of those component configurations in training. The effectiveness of changes in *hardware design* will be judged on increased efficiency and/or decreased cost with no degradation in training accomplishment. The criteria for judging the effectiveness of revised or newly developed *training methods* will be increased efficiency in terms of training time saved, decreased cost through aircraft hours saved, or an increase in capability of the graduate subject.

Category B studies will examine the interactive effects of the components of simulation; more specifically, how motion, G-seat, vision, math modeling, etc., interact to impact device training effectiveness. This will include study of the manner in which training methods such as knowledge of results and computer-aided instruction interact to influence training effectiveness. The specific interactions chosen for examination will be determined based upon: data obtained during the first phase of the program; considerations of the combinations; additional factors such as recommendations for research from the Future Undergraduate Pilot Training (FUPT) studies; and the length of time required to collect needed data.

Category C studies will involve investigation of candidate simulator configurations and their interaction with training methods (For example, the Instrument Flight Simulator (IFS) now being procured for ATC installation 1976–1980 might be the first, so addressed.). These candidate configurations will consist of combinations of hardware components found in *Category B* research to have the highest probability of being cost effective in the UPT program. One of the primary concerns in this stage of the research program will be the relationship between simulator configuration and training value as a function of time in the simulator. Interacting with this relationship is the training method employed during the time the student is in the simulator. Hence, the "simulators" studied at this time will be examined in a three-way interaction of device configuration, training method, and time. The studies will be essentially a rigorous evaluation of several candidate simulation systems. The results of this stage of the effort will provide information as to the most likely cost effective simulator, or family of devices, for implementation in UPT. This also will involve the study of substitutability which is the first stop in determining the most productive utilization of that hardware within the operational training environment. The procedure for determining substitutability will be to insert simulator training into various areas of the flying training curriculum in place of aircraft training. Amounts of simulator training will be varied in order to acquire a measure of the amount of aircraft training that can be replaced by the simulator. Results of this research will provide information on the effectiveness of simulation within the major phases of T-37 pilot training.

Category D, training syllabus development has as its purpose study of the complex interrelationships between amount, content, and sequence of simulator/aircraft training. The procedure to be employed will require the examination of the previously identified simulator system within the entire primary jet training phase of the UPT program, and follow-on studies to monitor the progress of simulator-trained students through advanced jet training and combat crew training (CCT). The output of these syllabus development studies will be recommendations for the effective utilization of the complete simulator hardware system defined during the preceding stages of research.

III. LONG RANGE GOALS

Under a supporting project (USAF Contract F41609-73-C-0038 with Life Sciences, Incorporated, Hurst, Texas; Dr. William G. Matheny, Investigator.), a list of specific research issues has been compiled on which data are required to answer questions by potential users concerning simulator requirements; a preliminary draft of this compilation is provided in Appendix B. This list was obtained as a result of exhaustive communications with a number of recognized experts in the field of training. Subsequent steps will: prioritize the list of issues, identify device capabilities for conducting the research, and provide suggested experimental designs for most efficient resource utilization. The research issues listed in Appendix B may be summarized in five general areas; i.e., motion, visual, engineering, performance measurement, and training methods. Following is a discussion of each of these general areas.

Motion Cuing Effects on Pilot Performance

The objective of these efforts is to relate pilot performance to off-the-shelf motion cuing systems under both instrument and contact flight conditions. The approach will be to configure ASUPT to simulate selected types of available motion systems for which acquisition costs differentials are know (for example: 3 DOF, $75K; 5 DOF, $180K; and 6 DOF, $225K). Each will be utilized with and without both G-seat and visual systems while experienced and novice pilots fly representative instrument and contact flight profiles. Differences, if any, in performance will be measured. Pilots will also provide subjective inputs in the form of awareness of which motion features they are experiencing. Data from this series of studies will either support the currently planned buys or identify areas for substantial cost avoidances. Useful data may be available as early as December 1974.

Visual Simulation

The objective of these efforts is to demonstrate the extent to which visually-dependent flying tasks can be trained in flight simulators for efficient transfer to the aircraft. The approach will include a full-scale demonstration of maximum effective visual simulator use in UPT, which will be conducted using full ASUPT capabilities and requisite innovative training methods. Formation, navigation, and even some air combat maneuvering (ACM) will be emphasized because of usefulness in generalizing to non-UPT training.

Student progress will be assessed frequently; performance in T-38 and combat crew training (CCT) will be monitored. Savings in flight time will documented. Data from these studies will serve as the basis for an ATC-developed required operational capability (ROC) for visual simulators in UPT.

Engineering Assessments

The objectives of these assessments are to accrue definitive data regarding motion equation computations, gravity alignment definition, frequency of response, platform deflection, color versus monochromatic display, collimated versus real imagery, and motion equation simplification; and to assess their impact on simulator performance and/or pilot acceptability. Once "perceptual equivalence" of the simulator to the aircraft has been established, the approach will be to use the ASUPT as a baseline against which other capabilities can be assessed, thereby avoiding complex time-consuming transfer of training paradigms. Studies of this sort will provide simulator design data. However, since they are anticipated to be smaller studies they will likely be interspersed between higher priority efforts.

Performance Assessment

The objective is to continue technique developments which reflect assessments of pilot skill levels in the simulator as valid indicators of ultimate aircraft performance. The approach is to use previous work such as adaptive modeling or computer-aided analytical methods as departure points for developing more refined assessment techniques. Emphasis will be on developing measures having practical utility in training management. Instructor and check pilot judgments will become more reliable and individual needs for training better determined.

Systematic Training Methods Studies

The objective of these studies is to assess the value of a vast array of available training techniques—both hardware and software—in making simulation systems more effective. The approach will be to conduct a series of studies which elevate training features; such as, automatic feedback, replay, varying difficulty levels, etc., to quantify their cost benefits. Findings of these studies will provide data on which to define future requirements and utilization techniques.

Table 1. **Phasing of Long Range Research Goals for ASUPT**

General Research Goals	Fiscal Years 74	75	76	77	78	79
1. Motion Cuing Effects on Pilot Performance:						
Nonvisual Tasks	S O	O	O	O	C	
Visual Tasks		S	O	O	C	
2. Visual Simulation in UPT		S	C			
3. Engineering Assessments	S O	O	O	O	O	O
4. Performance Assessments:						
Nonvisual Tasks	S O	O	O C			
Visual Tasks		S	O	O	O C	
5. Systematic Training Methods Studies		S	O	O	O	O

Note. — S = Start; C = Complete; O = Continuing.

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Table 1 presents a conceptual phasing of the research issues discussed previously based on currently anticipated availability dates for ASUPT. As ASUPT capability is still subject to change, the schedule provided is presented more as illustrative of research area phasing and information flow than as an actual event schedule. The blank spaces shown for early 1975 reflect current requirements wherein ASUPT will be down for installation and integration of the visual system. Curved lines in Table 1 indicate that findings in some efforts will have direct impact on activities in other areas; obviously there will be a significant amount of indirect interaction among findings in all research phases. Precise event scheduling also will be driven by ATC changes in student flow and pilot production rates.

IV. ASUPT UTILIZATION SCHEDULE

To provide for orderly acquisition of personnel resources required to support ASUPT research, it was necessary to forecast a relatively objective plan for device utilization. As in any long-range plan, this involved making some assumptions as to project duration and estimated times required in each phase of each project. Table 2 presents the current baseline plan.

As a first step in developing this plan, the activity phases of a complete research project were listed (bottom of Table 2). These phases, together with the estimated lengths in training weeks (top of Table 2) were derived from experience with similar kinds of simulator research projects conducted at AFHRL/FT, and at other similar research activities conducted over the past 20 years. The additional complexities of ASUPT were also considered.

With project phases identified and timelined, it was then possible to time-phase subsequent projects on the basis of device availability. As may be noted from the phase descriptions, the ASUPT is required for Phases E, F, and G (indicated by double lines in each project); this requirement is the pacing factor in the conduct of research. By matching the total ASUPT system acceptance date (all systems working and software developed) with the start of Phase E of Project 1, it is possible to project an estimated training week when activity must be started to meet the project schedule. For example, if ASUPT meets the above stated requirements by 6 January 1975 (believed to be a realistic estimate), detailed planning for the first project should begin 20 weeks earlier or 12 August 1974. To initiate specific planning activity earlier than this date would be a waste of very critical and limited manpower resources.

As may be seen from Table 2, the time phasing for five separate research projects is shown. The number of projects has no significance (it could have been one or fifty); it simply shows the phasing of the project steps involved. Currently, the objective of only the first project has been specified; e.g., a full demonstration of the capabilities of ASUPT (all features maximized to the best of existing knowledge) in the UPT T-37 Flying Training Program. The criteria of success will be the number of T-37 hours by type of flight training demonstrated to be replaceable through use of an ASUPT type device. These data will provide a baseline for subsequent simulator studies and reduce or eliminate the requirements for aircraft flights as criteria. It should be noted that the data collection phase for Project 1 covers 37 training weeks. This represents the conduct of two consecutive UPT classes through the T-37 phase. Since only 24 students per class (less attrition) can be carried, the study will require two UPT classes to obtain the necessary number of subjects to insure both experimenter and customer confidence in the results.

The subject of subsequent studies (i.e., Projects 2, 3, 4, etc.) may be follow-on efforts to examine specific areas of interest revealed in the first project, or they may be new thrusts such as visual/motion interactions, the effect of reducing the visual field of view on learning traffic patterns, changes in the visual scene data base, etc. They will likely address research issues of equal significance but lesser scope than Project 1. Therefore, it is anticipated subjects obtained from one class will be sufficient to provide confidence in the results obtained. Should it become feasible to use students for less than full class length (e.g., four weeks versus seventeen weeks), subsequent projects can be readily accommodated by simply moving the project start dates forward. In any event, the objective of the second study need not be definitized and people assigned earlier than 21 training weeks after simulator utilization has begun on Project 1 or, using estimates stated above, on 26 May 1975.

The final phase of completing this plan was to estimate the number and type of individuals required in each project phase. The number of people (by specialty title) are listed in the vertical column on the left of Table 2. It was realized that each person would not be required full time in each phase of each project;

Table 2 Projected ASUPT Utilization & Personnel Requirements by Research Project & Phase

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RESEARCH   (1) AAAA                         (2)AAAAAA                  (3)AAAAAA                 (4)AAAAAA                (5)AAAAAA
PROJECT        BBBBBBBBBBBB                    BBBBBBBBBBBBBBBB           BBBBBBBBBBBBBBBB          BBBBBBBBBBBBBBBB         BBBBBBBBBBBBBBBB
  BY                 CCCCCC                           CCCCCC                    CCCCCC                   CCCCCC                  CCCCCC
PHASE                  DDDDDDD                         DDDDDDDDDD                 DDDDDDDDDDD              DDDDDDDDDDD              DDDDDDDD
                              EEEE                           EEEEEEEE                  EEEEEEEE                 EEEEEEEE                 E
                                 FFFF                               FF                        FF                       FF
                                   GGGGGGGGGGGGGGGG.GGGGGGGGGGGGGGGGGG      GGGGGGGGGGGGGGGGGG        GGGGGGGGGGGGGGGGGG       GGGGGGGGGGGGGGGGGG
                                   HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH  HHHHHHHHHHHHHHHHHHHH      HHHHHHHHHHHHHHHHHHHH     HHHHHHHHHHHHHHHHHHHH
                                          IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII       IIIIIIIIIII              IIIIIIIIIII              III
TR WEEKS   0        10        20        30        40        50        60        70        80        90        100       110       120       130       140       150
INVEST     (1) AAAABBBBBBBCCDBBB....E...FFFFGGGHGGGHGGGHGGGHGGIGGIHGGIHGGIHGGIHGGIHIHIHIIIIIIII...............(4)AAAABABBBBBBBBCCDBBB...DE(5)AAAABABBBBBBBBCCDBBB...DE
INVEST     (1) AAAABBBBBBBCCDBBB....E...FFFFGGGGGGGGG(2)AAAABABBBBBBBBCCDBBB...DE...E...FFGGGHGGGHGGGHGGGGGHHIIIIIII..................(5)AAAABABBBBBBBBCCDBBB...DE
INVEST                                    (2)AAAABABBBBBBBBCCDBBB...DE(3)AAAABABBBBBBBBCCDBBB...DE...E...FFGGGHGGGHGGGHGGGGGHHIIIIIII...........
INVEST                                                              (3)AAAABABBBBBBBBCCDBBB...DE(4)AAAABABBBBBBBBCCDBBB...DE...E...FFGGGHGGGHGGGHGGGGGH
INVEST                                 (1)GGGGGGGGGGGGGGGGGGGGGGGGGGGGGG.....(2)FFGGGGGGGGGGGGGGGGG,  (3)FFGGGGGGGGGGGGGGGGGG.....(4)FFGGGGGGGGGGGGGGGGGG.
INVEST AT  (1)B.B.B.B.B.B.B....... .FFFFGGGGGGGGGGGGGGGGGG.GGGGGGGGGGGGGGGGGGGI.I.I(3)B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGGGI.I.I(5)B.B.B.B.B.B.B.B......
INVEST AT                                (2)B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGGGI.I.I(4)B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGGI
INVEST PM  (1).B.B.B.B.B.B.B.... .......GGGGGGGGGGGGGGGGGG.GGGGGGGGGGGGGGGGGGG.I.I.I(3)B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGG.I.I.I(5)B.B.B.B.B.B.B.B.. ..
INVEST PM                                (2).B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGGGG.I.I.I(4)B.B.B.B.B.B.B.B............FFGGGGGGGGGGGGGGGGGG.
IP         (1)BBBBBBCCDBBBD. .E.E.FFFFGGGGGGGGGGGGGGGGGG.GGGGGGGGGGGGGGGGGGI.I.I.I.I.I...................(4)BBEBBBBBBBCCDBBBD...E.E.E.E.FFGGGGGGGGGGGGGGGGGGI
IP         (1)BBBBBBBBBBBB. ..F.EFFFFGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG.I.I.I.I.I.I.I..................(4)BBBBBBBBBBBBBBBB..D..E.E.E.EFFGGGGGGGGGGGGGGGGGG.
IP                                       (2)BBBBBBBBBBCCDBBBD...E.E.E.E.FFGGGGGGGGGGGGGGGGGGI.I.I.I.I.........................(5)BBBBBBBBBBCCDBBBD...E
IP                                       (2)BBBBBBBBBBBBBBBBB..D..E.E.E.EFFGGGGGGGGGGGGGGGGGG.I.I.I.I.I.......................(5)BBBBBBBBBBBBBBBB..D..
IP                                                                  (3)BBBBBBBBBBCCDBBBD...E.E.E.E.FFGGGGGGGGGGGGGGGGGI.I.I.I.I...................
IP                                                                  (3)BBBBBBBBBBBBBBBB..D..E.E.E.EFFGGGGGGGGGGGGGGGGGG.I.I.I.I.I...................
RSCH ASST                     (1)FFFFGHGHGHGHGHGHGHGHGH GHGHGHGHGHGHGHGHGHGHHHHH(2)FFGHGHGHGHGHGHGHGHGHHH...(3)FFGHGHGHGHGHGHGHGHG-HH...(4)FFGHGHGHGHGHGHGHGHGHH
COMP SYS AN (1)B.B.B.B DB.BD...E...F...G.H.G.H.G.H.G.H.G.H.G.H.G.H.G.H.G.HG..H...(3)B...BB..BB..DB..D...E.D.E....FGH..GH..GH..GH.....H.....(5)B...BB..BB..DB..D...E
COMP SYS AN                              (2)B.B.B.B.B.B.B.D.B.D...E.D.E....FGH..GH..GH..GH.....H.....(4)B...BB..BB..DB..D...E.D.E....FGH..GH..GH..GH...H.
COMP SYS AN (1)BBBBBBBBDDDDDDDDEEEEFFFF..............(2)BBBBBBBBBBBBBDDDDDDDDEDEDEEEEFF......................(4)BBBBBBBBBBBBBDDDDDDDDEDFDEEEEFF..............
AERO ENG                                                            (3)BBBBBBBBBBBBBDDDDDDDDEDEDEEEEFF.........................(5)BBBBBBBBBBBBBDDDDDDDDE
ELEC ENG   (1)BB.BB.BBDBDBD.D.E.E...................(2)BB.BB.BB.BB.DBBD.D.DEDEDE(3)BB.BB.BB.BB.DBBD.D.DEDEDE(4)BB.BB.BB.BB.DBBD.D.DEDEDE(5)BB.BB.BB.BB.BB.DBBD.D
VIS SYS AN (1)B.. B...B.......E...F................(2)B...B...B...B.......E.......F(3)B..B..B...B......E.......F(4)B..B..B...B......E.......F(5)B..B..B...B.....E
MATH       (1)BB B.B.BDB..D...E                    (2)BB.BB.B.B.B.D.B.D...DE.DE(3)BB.BB.B.B.B.D.B.D...DE.DE(4)BB.BB.B.B.B.D.B.D...DE.DE(5)BB.BB.B.B.B.D.B.D...D
MATH       (1)B BBBBBBBBBBDDDD.F.F....GHGHGHGHGHGHGHGHGHHHGHGHGHGHGHGHGHGHGHHHHHH(3)BBBBBBBBBBBBBBBBBDDDDDDDDEEEEFFGHGHGHGHGHGHGHGHGHHH...(5)BBBBBBBBBBBBBBBBBDDDDD
PROG                                     (2)BBBBBBBBBBBBBBBBBDDDDDDDDEEEEFFGHGHGHGHGHGHGHGHGHHH...(4)BBBBBBBBBBBBBBBBBDDDDDDDDEEEEFFGHGHGHGHGHGHGHGHGHH
PROG       (1)BBBBBBBBBDDDDDDDDEEEEFFFFGHGHGHGHGHGHGHGHGHHHGHGHGHGHGHGHGHGHGHHHHH(3)BBBBBBBBBBBBBDDDDDDDDEDEDEEEEFFGHGHGHGHGHGHGHG.HH...(5)BBBBBBBBBBBBDDDDDDDDE
PROG       (1)BBBBBBBBBBBB........F...HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH(3)BBBBBBBBBBBBBBBB..............F.HHHHHHHHHHHHHHHH HH...(5)BBBBBBBBBBBBBBBB....
PROG                                     (2)BBBBBBBBBBBBBDDDDDDDDEDEDEEEEFFGHGHGHGHGHGHGHGHG.HH...(4)BBBBBBBBBBBBBDDDDDDDDEDEDEEEEFFGHGHGHGHGHGHGHGHG.H
                                         (2)BBBBBBBBBBBBBBBB..............F.HHHHHHHHHHHHHHHHHHHH...(4)BBBBBBBBBBBBBBBB..............F.HHHHHHHHHHHHHHHHHHHH
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PHASE DEFINITIONS			
	A DEFINITION OF REQUIREMENTS/OBJECTIVES	D DEFINITION OF CONFIGURATION THRU SOFTWARE CONTROL	G COLLECT EXPERIMENTAL DATA
	B DEVELOPMENT OF RESEARCH PLAN	E CONFIGURE AND DEBUG ASUPT SOFTWARE	H CONDUCT DATA PROCESSING & ANALYSIS
	C PREPARATION & COORDINATION OF RESEARCH AGREEMENT	F CONDUCT OF SMALL PRETEST & COMPLETE USER TRAINING	I COMPLETE PROJECT REPORT

the estimated amount of required time for each person may be noted by observing the number of training weeks identified by person/phase/project. If these estimates prove accurate, the total number of personnel required to conduct continued research on ASUPT equals the total positions identified; in this case, 28 personnel. Furthermore, an estimated time when these people must be on board and qualified in ASUPT use can be determined by noting when activity is first shown on any line. Obviously, necessary orientation and familiarization with the ASUPT will require added lead time.

As an operating philosophy, it is planned to use a principle investigator and an associate investigator for each project: this associate investigator will be transferred to become team leader on the next project when Phase 1 begins. He will be replaced by a less experienced investigator who assists in finishing the two shift research effort of the first project. Thus, both growth potential for junior investigators and continuity of research efforts are insured.

As with any plan of more than one year (and perhaps less), revision will be made in light of experience gained. However, the plan as represented in Table 2 provides a solid baseline from which to depart as such changes become indicated.

V. POTENTIAL NEAR-TERM RESEARCH PROJECTS

The approach to ASUPT research planning as presented earlier must be tempered by more realistic considerations when specifying and time phasing projects. While not all inclusive, these considerations include user requirements, device capability and availability, manpower and dollar resources, and local base support. Unfortunately, due to changing political and financial pressures, these factors are in a continuous state of fluctuation. As a result, while the goals of the long range plan will eventually be met, the scheduled objective, sequence and size of specific interim studies (which comprise the total program), must remain flexible. For example, as noted earlier, acceptance of the ASUPT simulator minus visual capability has slipped some four months past the original schedule. Thus, capability for the conduct of early studies concerning basic simulator capability requirement also slipped. However, to provide a basis for short-term utilization of the ASUPT, an effort has been made to identify specific research issues which can be addressed in a short period of time using T-37 flight instructors or "throw away" student subjects without significant impact on ongoing ATC UPT. Specifically, the investigations suggested here are those which might be carried out during the period between acceptance of the ASUPT sans visual display system and the time of delivery of that system.

Investigations using the system during this period can serve three useful purposes: (a) a learning period for both maintenance and research personnel during which they become familiar with the equipment, its capabilities and its idiosyncrasies; (b) a shake-down period in which the equipment is exercised and remaining "bugs" may be discovered and remedied; and (c) providing useful data and information for training simulator specifications. Following is a discussion of three potential studies.

Motion Cues

The specific experimental question to be addressed by these investigations is "under what method of introducing motion cues and across what conditions of flight are the control performances of experienced pilots equivalent?" The approach taken supposes that if two physically measurable systems are different but their operation results in no measurable differences in the performance of experienced pilots then the physical differences are perceptually or behaviorally equivalent and are not different for purposes of a training simulator.

The independent variable of prime interest is that of the motion cue condition. What is sought is a determination of whether pilot performance varies as a function of motion cue conditions across different maneuvers and for different levels of external disturbances. The motion cues to be investigated in ASUPT fall under the three broad categories of: (a) platform motion, (b) a gravity alignment, and (c) g-seat. A list of 21 experimental conditions and related condition descriptions is provided in Table 3 and provides a logical basis for an experimental plan.

Table 3. **Experimental Conditions for Interim ASUPT Motion Studies**

Experimental Condition	Condition Description[a]
1.	No Motion
2.	P, R (Platform)
3.	P, R, Y (Platform)
4.	P, R, Y, H (Platform)
5.	P, R, H (Platform)
6.	P, R, H, L (Platform)
7.	P, R, H, F/A (Platform)
8.	P, R, H, L, F&A (Platform)
9.	P, R, Y, H, L (Platform)
10.	6 Degree of Freedom Platform
11.	6 Degree of Freedom Platform with Gravity Alignment
12.	P, R, (Platform) with Gravity Alignment
13.	P, R, H (Platform) with Gravity Alignment
14.	P, R, Y, H, L (Platform) with Gravity Alignment
15.	6 Degree of Freedom Platform with Full G-seat
16.	6 Degree of Freedom Platform with Full G-seat and Gravity Alignment
17.	Full G-seat only
18.	P, R, (G-seat), H (Platform)
19.	P, R (Platform), H (G-seat)
20.	P, R (G-seat)
21.	P, R, F&A (Platform)

[a]Legend:

P - Pitch	H - Heave
R - Roll	L - Lateral
Y - Yaw	F&A- Fore and Aft

Experimental Plan. Table 4 is designed to show the experimental conditions relevant to providing information about particular experimental questions concerning motion. The experimental procedure is one in which the 21 conditions may be run in three experimental sessions and provide information relevant to the 10 experimental questions which are posed. The experimental questions have been selected such that successive data runs can be made with experimental conditions on subsequent runs being dependent upon the findings of earlier runs. A "sorting out" approach is used in which the various combination of conditions are examined to determine whether they effect any differences in pilot performance and what the relative contribution of the conditions are to performance variability. The effects found under one set of conditions are used to guide the selection of the experimental conditions to be used in the next run.

Under the proposed experimental procedure as outlined in Table 4, the first experimental session would cover Experimental Conditions 1, 10, 11, 15, 16, and 17. (The sequence of experimental conditions can be altered but the one presented appears most practical at this time.) Results from performance under these conditions are intended to show whether or not the major conditions of simulations of: (a) no-motion, (b) six degree of freedom platform, (c) six degree of freedom platform with gravity alignment, (d) six degree of freedom platform with full g-seat, (e) six degree of freedom platform with full g-seat and gravity alignment, and (f) full g-seat only, differentially affect performance, and, if so, what are the relative effects.

If Experimental Conditions 1 and 10 differentially affect performance, Session Two will be concerned with obtaining data on Experimental Conditions 2, 3, 4, 5, 6, 7, 8, 9, and 21. The results from these conditions are intended to determine what combinations of degrees of freedom of motion of the platform are equivalent.

Experimental question number 3 is answered by comparison of Conditions 10 and 11 with experimental run 1. This question concerns the contribution that the gravity alignment cue makes to the maximum degree of freedom platform.

Table 4. **Experimental Sessions for Assessing Motion Questions**

Exp Session	Experiment Conditions 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Major areas of simulation	x									x	x				x	x	x				
2. Minimum degrees of freedom		x	x	x	x	x	x	x	x	x											x
3. Gravity alignment contribution - maximum platform										x	x										
4. Gravity alignment contribution - nominal platform					x								x								
5. Gravity ·..ignment contribution - maximum platform plus G-seat															x	x					
6. Gravity alignment contribution - minimum platform		x										x									
7. Longitudinal acceleration cue contribution - maximum platform - gravity alignment or fore and aft									x	x				x							
8. Substitute gravity alignment for fore and aft - maximum platform										x				x							
9. Substitute gravity alignment for fore and aft - minimum platform												x									x
10. G-seat substitution for platform		x			x													x	x	x	

In Experimental Session 3, the six remaining experimental conditions of 12, 13, 14, 18, 19, and 20 are added. Comparison of Experimental Condition 13 with Condition 5 is intended to answer the question with respect to a contribution of gravity alignment given a nominal platform. What constitutes a nominal platform has been assumed to be that represented by Condition 5; i.e., one with pitch, roll, and heave. However, the results of the analysis of Experimental question 2 may change what is considered to be nominal platform and, therefore, change these conditions somewhat.

Comparison of Conditions 15 and 16 is designed to give information about the contribution of gravity alignment when the maximum platform is used with the g-seat.

Addition of Condition 12 allows the comparison between Conditions 2 and 12 and gives information about the contribution of gravity alignment with the minimum platform; i.e., one which provides only pitch and roll stimuli.

The addition of Condition 14 allows for a comparison of that condition with Conditions 9 and 10 and gives information about the longitudinal acceleration cue contribution when a maximum platform is used; i.e., whether the gravity alignment or fore-and-aft translation is the better cue or whether it has any effect at all upon performance.

In carrying out the experimental runs, it is proposed that the experimental conditions be examined under several representative task conditions. These tasks are suggested as being combinations of the fundamental transitional tasks and steady state flight paths as proposed by Meyer and Eddowes (*Development of a Behavioral Taxonomy of Undergraduate Pilot Training (UPT) Tasks and Skills.* AFHRL-TR-74-33. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, in press.) It is also proposed that the fundamental nature of the control task required of the pilot in performing these steady state flights or transitional tasks is a function of the external forcing function or disturbance acting upon the system. His control behavior will be affected by the nature of this distribution function and it is, therefore, proposed that three levels of disturbance be imposed upon each of the basic flight tasks in order to determine the equivalence of various physical systems across representative tasks and disturbances.

Motion Requirements for Basic Instrument Training

Considerable monies have been spent in procuring modest size motion systems for simulators procured during the past five years. These procurements have been based generally on emotional appeal that "most is best" and on engineering developments rather than an actual measurement of what is really used by pilots performing conventional flight maneuvers. The study discussed earlier will provide an extensive examination of many facets of motion cuing. However, a short term study which requires fewer subjects and less time will permit an early examination of a different aspect of the problem.

Research Question. This study will investigate to what extent pilots use the motion capability provided in the ASUPT in the conduct of T-37 instrument flight maneuvers. Later, when the visual system is installed, a similar short term follow-on effort will investigate differences in motion usage while performing more demanding contact flight maneuvers.

Approach. When outstanding hardware and software items have been cleared from the ASUPT system, it will be necessary to have highly experienced instructor pilots fly and record model performances of all UPT T-37 instrument maneuvers (from failing to excellent) for use in subsequent training research. These performances, while not flown by beginning students, may be assumed to place the same demands on the ASUPT as would be expected from trainees.

Through development of programs designed to record motion parameters during model maneuver data development, it is possible to obtain data relative to the amount of motion used. This capability, inherent in the ASUPT, will be used to compile information concerning the frequency, duration and extent of motion usage for each degree of freedom.

Analysis of these data will provide information concerning motion performance requirements for performing conventional instrument and contact maneuvers in low performance aircraft. While perhaps not applicable to student training or to simulators for high performance aircraft, these findings should be useful to personnel defining system specifications for refresher training devices. This study can be performed at low cost and offers an opportunity to make a substantial contribution to the simulator usage data bank.

Evaluation of Objective Measures of Flying Performance

Research Question. One of the most important features of ASUPT will be the automated objective scoring system for evaluating flying performance. Such measurement capability will alleviate many of the routine "bookkeeping" functions which the instructor pilot must presently fulfill. Although the measurement system will be generated using the expertise of the experienced flight instructor, the question of the relationship between the objectively derived scores and the judgments of the instructor pilot remains. In other words, how well do objectively derived measures predict instructor evaluations of flying performance? The establishment of substantial relationships between these two methods of evaluation would facilitate the study of transfer effects from the simulator to the aircraft.

Approach. It is proposed that a small set of instrument flight maneuvers be selected on the basis that they cover the range of skills required during the instrument phase of flight instruction. For each measure selected, a number of flights will be recorded representing different levels of performance and emphasizing different types of errors. Using the playback feature of ASUPT, instrument check instructors will be asked to evaluate these flown maneuvers. In this manner the equivalence between the automated objective scoring system and instructor pilot evaluations will be established.

VI. SUMMARY

This report and its attachments provide a description of research equipment, either available or soon to be operational, at the USAF Pilot Training Research Facility. Also included is a preliminary list of research issues which may be addressed using ASUPT capabilities. Research philosophies and utilization concepts discussed represent a baseline from which to depart in development of a data base for use in optimizing simulator utilization.

The research plans presented are limited in detail and show issues to be addressed and overall direction as opposed to more specific details relevant to each research issue. Specific details concerning the conduct of each research project will, more appropriately, be included as a part of each work unit, research plan and/or research agreement.

Acceptance procedures for the ASUPT system included an estimated four month period between completion of simulator hardware, and shut down for installation of the visual system. Some of this time will be required for clearing outstanding problem areas, for orientation and system training, and for developing software for use in subsequent projects. Depending on the rapidity with which these essential requirements are completed, there may also be some time available for short term research efforts. Therefore, this plan includes three projects which will be implemented (not necessarily in the order presented) on a time available basis if this "window" occurs.

The first of these research issues concerns motion cuing effectiveness. The project as discussed herein permits collection of portions of the total data requirement; thus, it may be initiated and stopped in conjunction with simulator availability for short term research efforts. Two other short term projects (to be implemented if the research window is large enough) involve: (a) a motion utilization measurement effort intended to provide simulator design enlightenment; and (b) an effort which has as its thrust the validation of recorded model instrument maneuver performances as representative of the in-flight grading procedures for assessing student pilot performance currently used in ATC.

In summary, the plan presented herein provides a baseline for long term ASUPT utilization. As data are acquired and new thrusts conceived, research activities will be redirected to address new issues, thereby maximizing dynamic responses to user's needs.

APPENDIX A: DESCRIPTION OF ASUPT AND OTHER FLIGHT TRAINING EQUIPMENT LOCATED AT THE AFHRL/FT RESEARCH FACILITY

The technical information contained herein has been compiled from a variety of sources. It covers only the highlights of the respective devices. Readers interested in more detail are referred to the references contained at the end of each section.

I. ASUPT[1]

The major components of the ASUPT system are shown in block-diagram form in Figure A1. Subsequent paragraphs describe the system components.

Motion System

Onset. A synergistic six degree-of-freedom motion system has been selected for ASUPT. Each motion platform is driven by six hydraulic actuators and has six passive actuators for safety purposes. The actuators have 60" travel and together provide the following displacement capabilities:

Vertical	+ 39", – 30"	Pitch	+ 30°, – 20°
Lateral	± 48"	Roll	± 22°
Longitudinal	+ 49", – 48"	Yaw	± 32°

These excursions, in turn, are sufficient for onset cues (with subsequent washout) of the following magnitudes:

Vertical	± 0.8 g	Pitch	$\pm 50°/Sec^2$
Lateral	± 0.6 g	Roll	$\pm 50°/Sec^2$
Longitudinal	± 0.6 g	Yaw	$\pm 50°/Sec^2$

Total Payload: 17,000 lbs
Total Weight on Floor 26,500 lbs

Sustained. The left-hand (student's) seat in each cockpit consists of 31 pneumatically driven, individually controlled elements:

- Seat pan - sixteen 4" x 4" cells
- Back Rest - nine 5" x 7" cells
- Thigh Panel - three cells on the outer side of each thigh

In addition, the tension in the student's lap belt is varied by a small actuator. By altering the contour of the seat pan and back rest and by changing the force exerted by the lap belt, the sustained pressures sensed in the back, buttocks, thighs, and abdomen during flight are simulated.

Visual System

Each cockpit is virtually enclosed within the seven-channel display subsystem (Figure A2). Each channel consists of a cathode ray tube (CRT) and a set of in-line optics (Figure A3). The optical components collimate the light rays to provide an infinity image and match the scenes from adjacent CRTs to produce a continuous field-of-view which essentially duplicates that of a T-37 aircraft: ±150° horizontally and +110°, –40° vertically (Figure A4). The computer generated images appear on the appropriate CRTs, depending on the location and attitude of the aircraft. The ASUPT visual system is unique in terms of its capability to provide relatively complex scenes in proper perspective over a very large field-of-view during unprogrammed flight paths anywhere within a 500 nautical mile by 500 nautical mile by 100,000 foot airspace.

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[1]Compiled by Capt Frank E. Bell, III, AFHRL/FT.

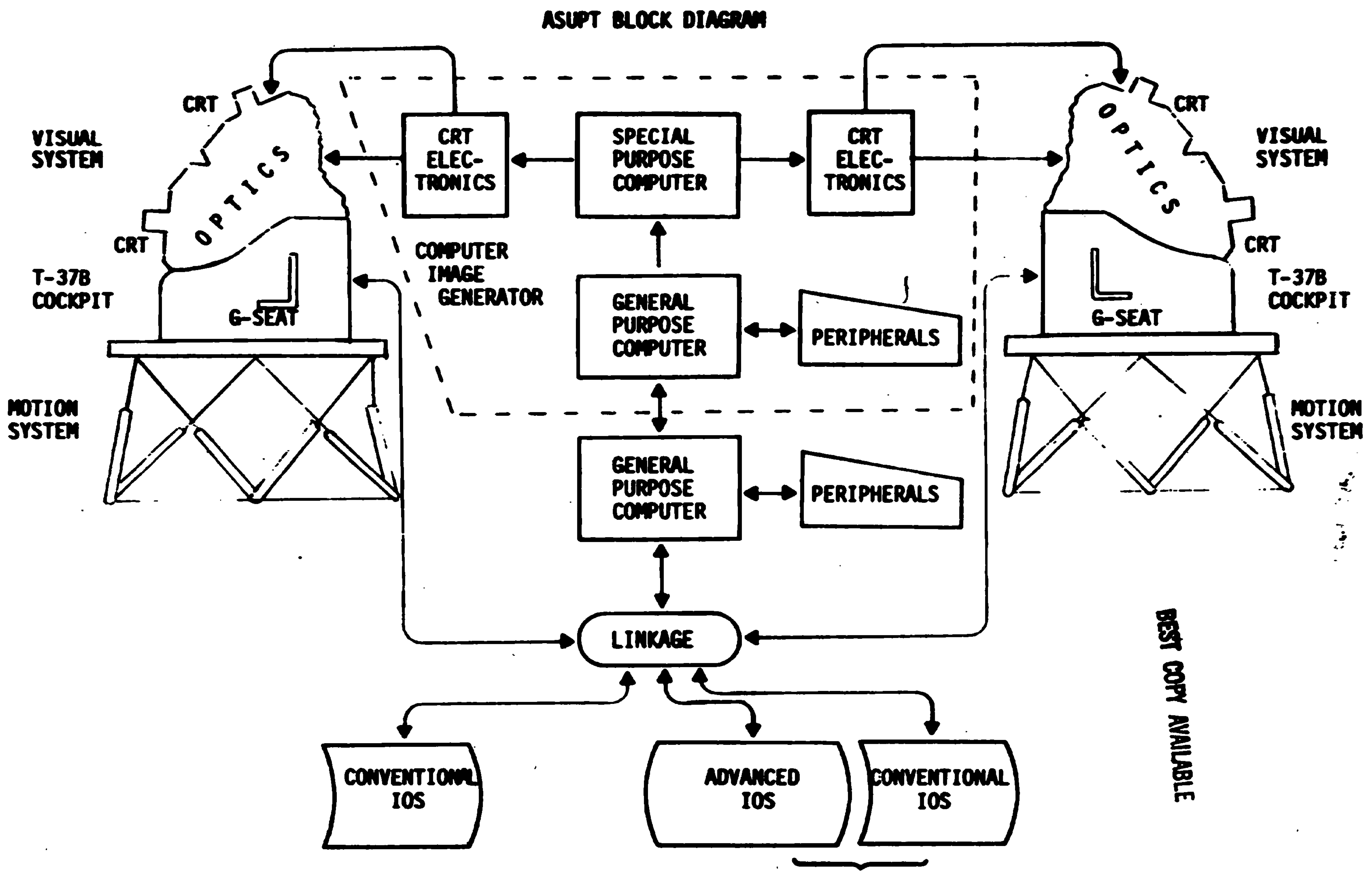

Figure A1. ASUPT schematic.

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The CRTs used in the display system are the largest ones in existence, with an overall length of 40" and a chordal diameter of 36". The faceplate is part of a spherical surface 48" in diameter and subtends an 80° angle. Noteworthy features of the tube and its electronics include 1,023 scan lines, 1,000 elements/line, 30 frames/second, 7 arc-minute resolution, and 600 foot-lamberts highlight brightness. PT462, a high-efficiency, green-tinted phospher which matches the spectral characteristics of the optics well, is used to produce monochrome scenes.

The passage of images through the optics is illustrated in Figure A5. The polarizers and filters allow the wanted (infinity) image to be transmitted to the pilot while extinguishing the real image and multiple reflections. The path which the wanted image travels results in a significant loss in brightness; the transmission efficiency is approximately 1%. The highlight brightness seen by the pilot, consequently, is 6 ft-lamberts.

The computer image generator (CIG) produces scenes in the following manner. Each object to be displayed is modeled as a set of convex polygonal surfaces. Specifically, the X, Y, and Z coordinates of each vertex of the object are stored on disc along with information associating the vertex with an edge, the edge with a plane polygon, and the polygon with the object. As the aircraft moves through the environment, the computer extracts from mass storage only the edge data in the immediate vicinity of its current position. This eliminates processing of data for objects obviously too distant to be seen and allows the number of stored edges to be many times the number of edges actually displayed.

The potentially visible edges are geometrically projected onto seven display planes in order to determine in which channel each is to appear. The intersection of the edges with the scan lines are then computed, priority conflicts resolved, and "gray shades" assigned to the individual element.

The ASUPT CIG is capable of displaying 2,500 edges, which may all be used in one cockpit or may be shared in any desired ratio between both simulators. For example, if an airwork sortie is underway in cockpit A and traffic pattern practice in B, 500 edges are processed and displayed for A, 1,500 for B. A and B need not be operated within any limited geographic region of the environment model; each is free to fly independently. Special effects such as atmospheric haze and ceilings are incorporated in the system, as are three versions (day, dusk, and night) of the basic model. In addition to fixed objects, the system can display a "moving model" (e.g., another aircraft) for formation or one-on-one training.

The delivered environment model will contain approximately 100,000 edges. The local area of Williams AFB and its auxiliary field, the T-37 contact practice areas, and a 50-mile perimeter around these regions will be modeled with all significant landmarks and features. Surface patterns will occupy the remaining area out to the boundary of the 500 by 500 NM region. Both the simulator and the CIG have been designed for eventual expansion to an area 1,250 by 1,250 NM. Changes or additions to the model are easy to make.

Computers and Electronics

Both the simulator and image generator use the Systems Engineering Laboratories (SEL) Systems 86 general purpose computer, a 32-bit word machine with 600 nanosecond memory cycle speed. Characteristics of the Systems 86 which make it especially well-suited for real-time simulation applications include the following:

Fast instruction execution times (e.g., 1.2 microsecond full word add), which results in a processing speed of 700,000 instructions per second.

Efficient floating point operations only 10% slower than fixed point.

Direct addressing of any bit, byte, halfword, or word anywhere in 128K of memory.

Halfword instructions which can be stored two per memory location.

Very-high-speed I/O channels providing a data transfer rate of 1.67 mission words per second.

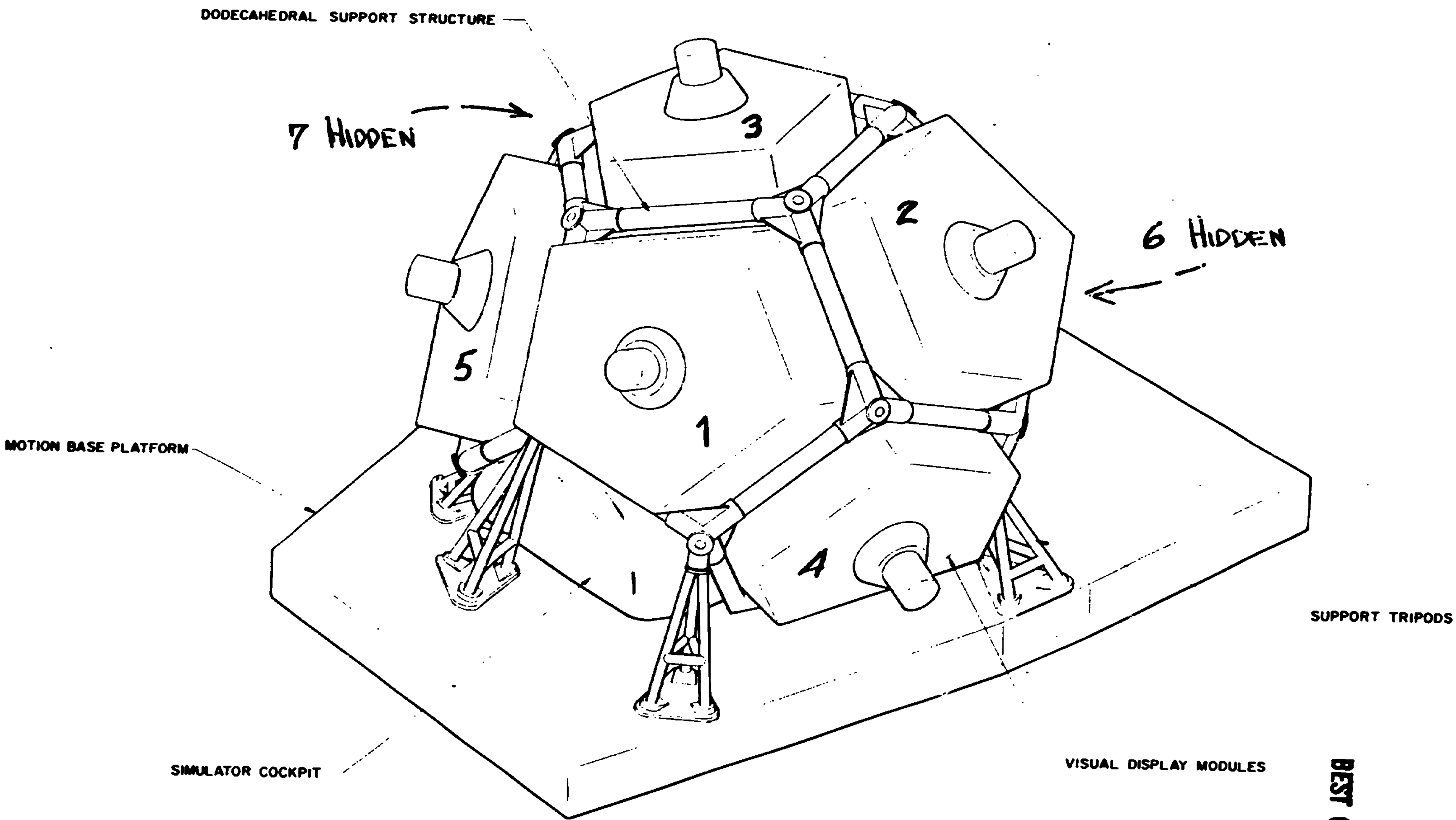

Figure A2. **Visual display configuration.**

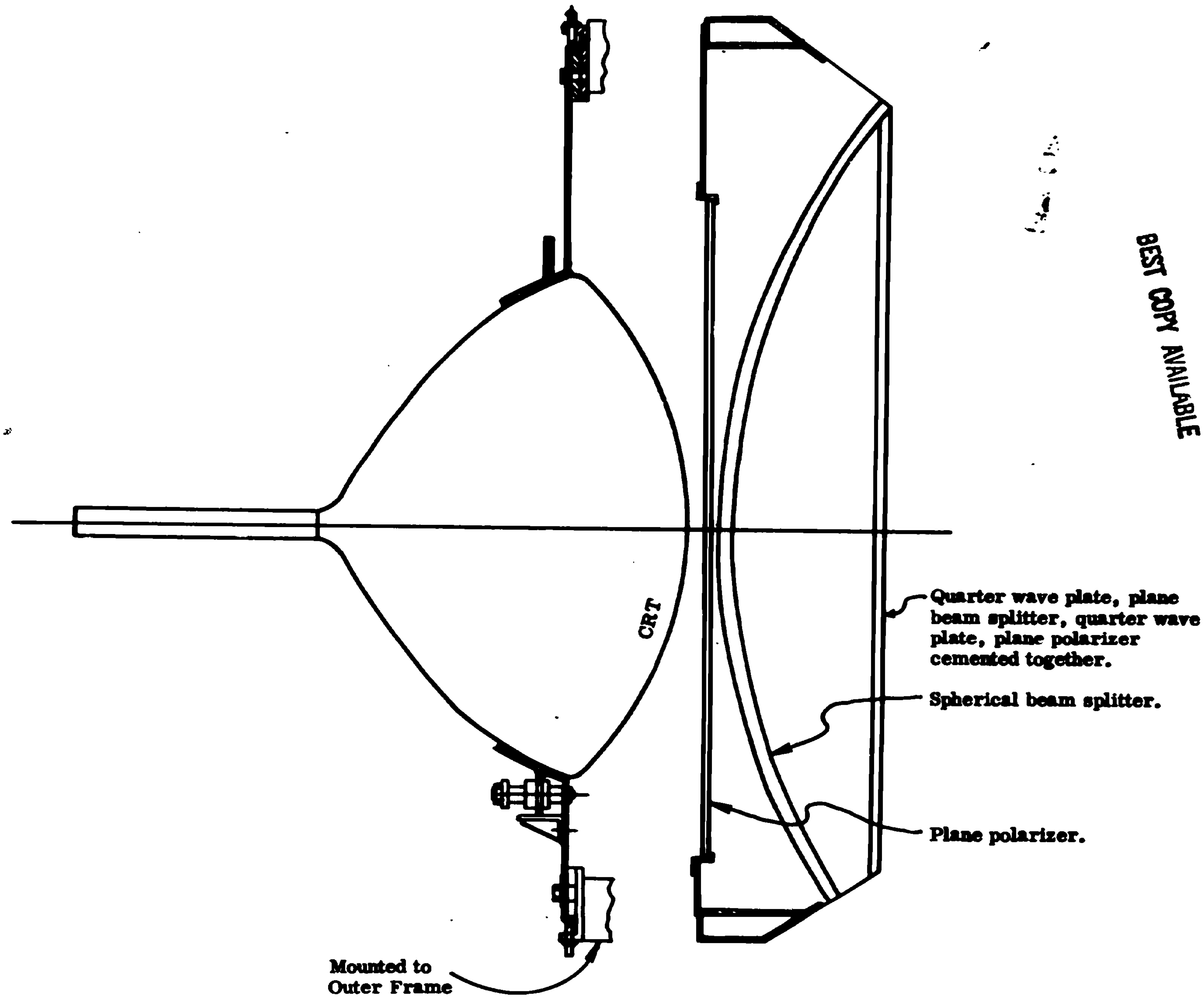

Figure A3. **Cross section of typical farrand in-line infinity window.**

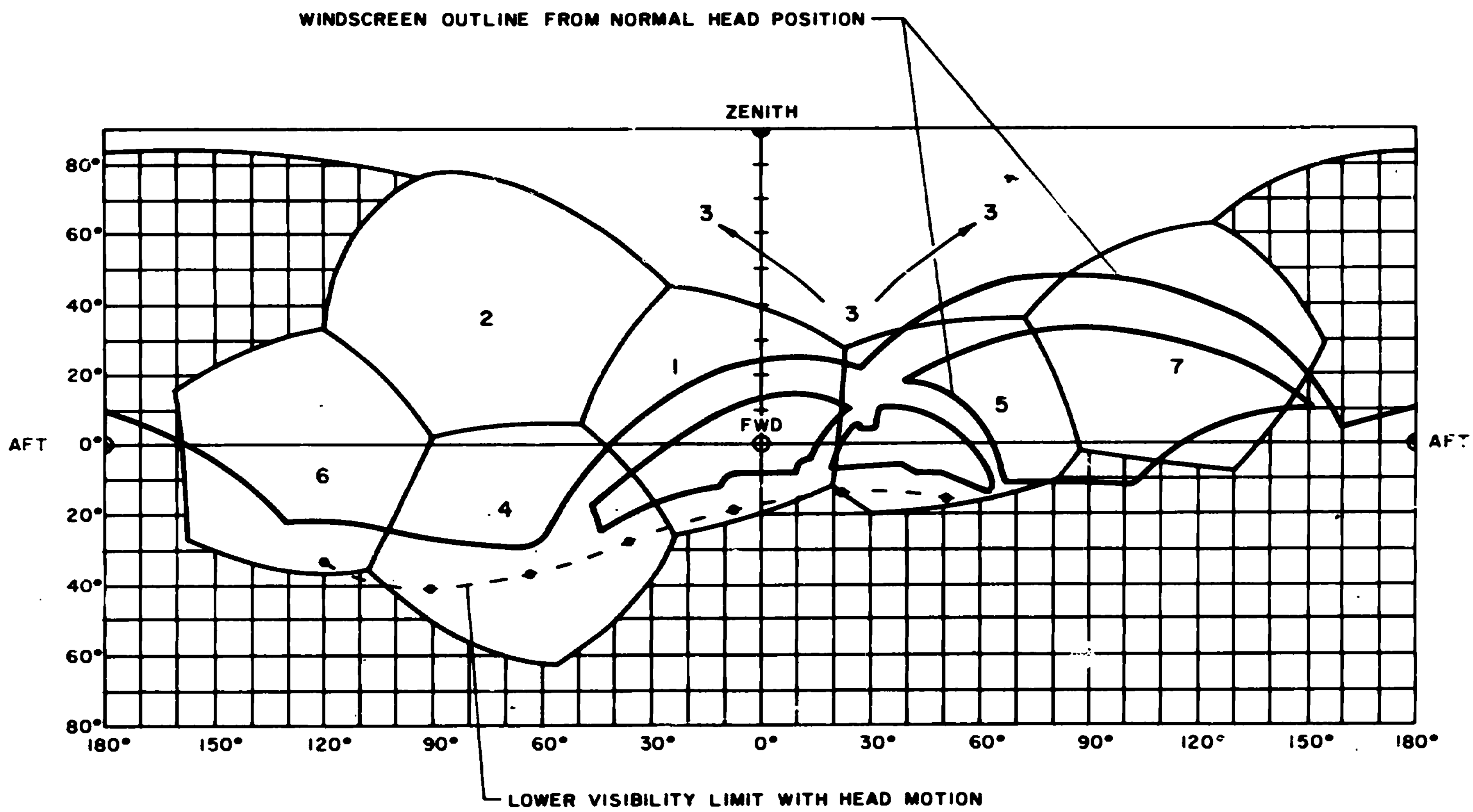

Figure A4. **Visibility diagram (pilot's position).**

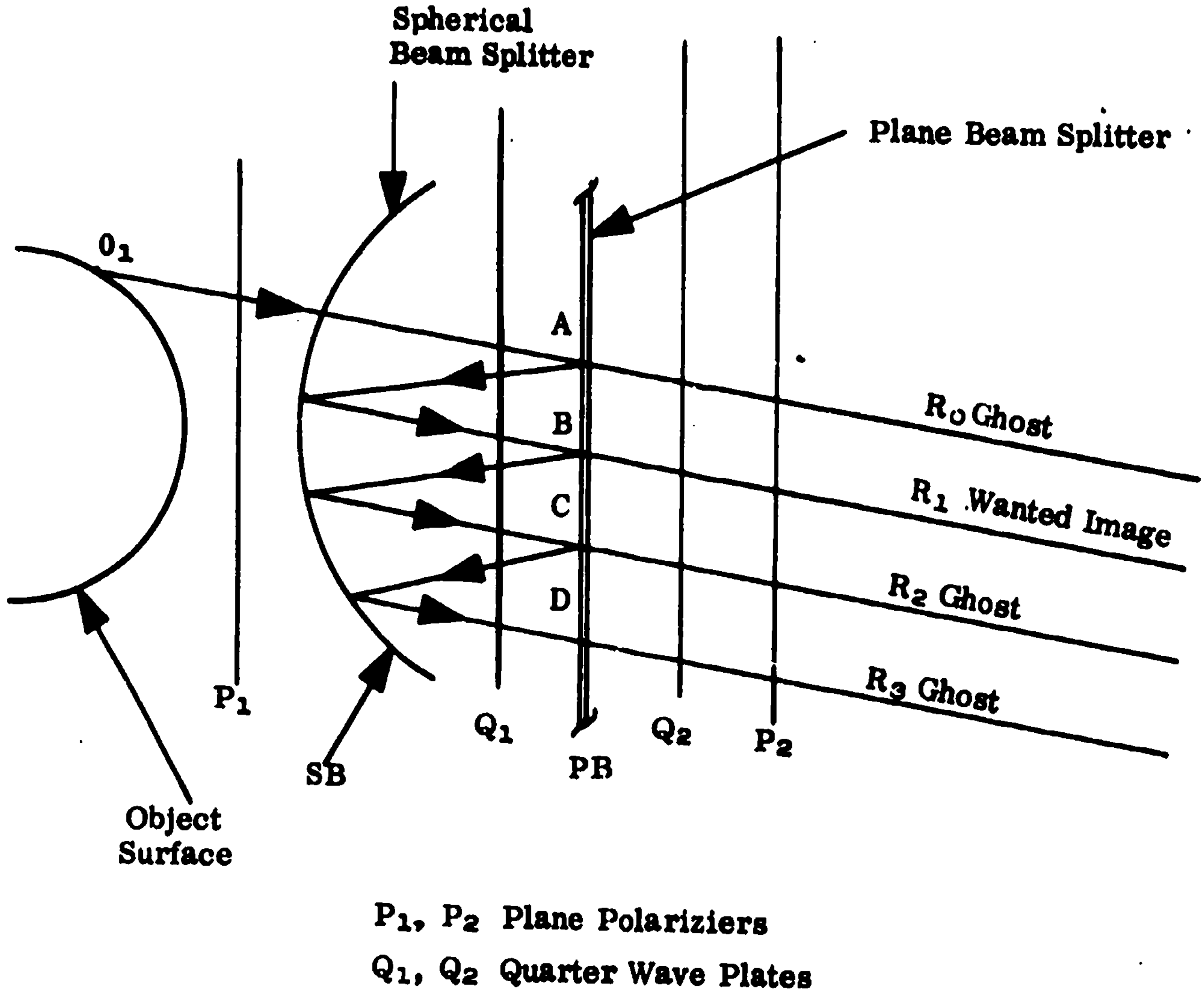

Figure A5. **Schematic illustration of farrand infinity in-line optical display.**

The general purpose equipment is tabulated below:

Item	Simulator (Singer)	Image Generator (General Electric)
Central Processing Units (ea)	1	2
Core Memory (Words)	96K	32K
Disc Memory (bytes)	24 Million	16.8 Million
Magnetic Tape Units (ea)	2	1
Line Printers (600 lines per minute)	1	1
Card Reader/Punch (200 cards per minute read, 100 cards per minute punch)	1	1
Teletypewriter (ea)	1	2

The special purpose computer is a hard-wired device which performs the extremely high speed operations necessary to transform the environment data into correct perspective images on all 14 CRTs every 13th of a second. Its 16 racks include 176K words of dedicated core memory and over 100,000 integrated circuits.

Two independent sets of electronics contain the sweep and function generators, video and deflection amplifiers, and power supplies which drive the CRTs.

Instructor/Operator Stations

The facility has the capability for control inputs to each simulator from three different types of instructor/operator stations. These stations are referred to as the conventional, in-cockpit, and advanced stations. Collocated with one conventional station is the advanced experimenter/instructor/operator station.

The conventional instructor/operator station (CIOS) contains all controls, indicators, displays, recorders, instruments, lights and other equipment necessary to set up, control, and monitor the simulated training mission. The distinguishing feature of the CIOS is that it utilizes repeater cockpit instruments and manual insertion of training conditions similar to existing mission simulators.

The in-cockpit instructor/operator station (ICIOS) is located to the right of the instructor pilot's seat. Its position is such that it may be shielded from the student's sight when the instructor pilot is in the cockpit. The ICIOS console consists of a small CRT display, a keyboard for inputs, and several switches. From this station, the instructor can interact with the computer to call up malfunctions, performance demonstrations, and all other advanced training capabilities. When solo, the student will be able to see the in-cockpit console CRT and may be supplied training information on this display.

The advanced instructor/operator station (AIOS) contains a keyboard, four computer driven CRT's, a stick for providing control inputs to either simulator, and other equipment required to implement the advanced instructor provisions described below. Two of the CRT's display seven color alpha numeric information in a raster scan format. The other two can also provide alpha numeric characters, but are designed for graphic information such as navigation charts, ground controlled approaches (GCA), and lead and wing aircraft situation display for formation or one-on-one training; these CRT's use a stroke scan format. Any information available at the CIOS can be reformatted and displayed on an AIOS CRT. In addition, virtually any parameter in the computer can be called up for display. For example, a real-time plot of airspeed versus altitude during final approach can be generated and displayed along with a prestored plot of the ideal approach. A hard copy can be produced to use when debriefing the student. Finally, the AISO is located immediately adjacent to one of the conventional stations to permit the study of potential console designs which contain a mixture of standard and advanced instructional features. In this mode, the console is termed the combined IOS.

At each CIOS are three video monitors, one providing a closed circuit TV picture of the student in the cockpit and the other two displaying selectable channels of his visual scene.

Advanced Instructional Features

The ASUPT research facility has extensive capabilities involving instructional techniques, some of which are not now available in conventional simulators. These capabilities include: selective task sequencing; variable task difficulty and complexity; selective malfunction insertion; freeze; rapid reinitialization; automated demonstration; knowledge of results; and self confrontation. Following is a brief discussion of each of these capabilities:

1. *Task Sequencing*. There are four methods of sequencing possible: Instructor Directed Manual (IDM); Student Directed Manual (SDM); Explicit Ordered Automatic (EOA); and Computer Ordered Automatic (COA). In IDM, the instructor pilot (IP) selects the next task depending upon the student's performance, required accomplishments, and in general, the IP's judgment. The SDM mode allows each student to select the task in an order satisfactory to himself. This presupposes a knowledge of required elements and their interrelationships, but it has a sound basis in learning technology. EOA permits preprogramming of task sequence prior to a sortie. This mode provides the instructor or experimenter with a fixed task order for a group of students; such an arrangement is mandatory for rigid experimental control. COA is the ultimate approach: the computer selects the sequence based on task importance, difficulty level, student ability and previous performance to provide optimum individual sequencing.

2. *Task Difficulty and Complexity*. Any given task may have several levels of difficulty and complexity. These variables are dependent on four factors.

a. *Degrees of Freedom of Motion*. Aircraft motion is a combination of displacements in six dimensions: longitudinal, lateral, vertical, roll, pitch, and yaw movements. Simulated aircraft movement can be restricted to any combination of the six degrees-of-freedom desired.

b. *Aerodynamic Response*. The simulator allows for variation of aircraft response to control movements. For example, stability could be decreased to increase task difficulty.

c. *Malfunction Insertion*. The type and number of malfunctions determine task loading and, therefore, influence overall task complexity and difficulty.

d. *Environmental Factors*. Wind velocity and direction, temperature, and turbulence affect maneuver difficulty.

3. *Malfunction Insertion*. The inclusion of malfunctions (simulated emergencies) into training may be accomplished one of three ways.

a. *Direct* – immediate initiation, performed from any instructor location.

b. *Automatic/Explicit* – insertion into the mission when a predetermined set of conditions occur.

c. *Automatic/Probabilistic* – insertion into the mission as a function of several parameters, one of which is random.

4. *Freeze*. The freeze mode is similar to existing simulator capabilities. Its selection by the student, instructor, or experimenter stops the simulator; all instruments and visual displays stop in their position. This capability gives the student time to catch up, lets the instructor's briefing remain current with the aircraft, or lets him emphasize a particular point.

5. *Reinitialization*. This is the ability of the system to place the simulated aircraft at a particular point in space and with a given configuration without "flying" it there. For example, in learning the turn to final the student can start from the downwind, fly to touchdown, reinitialize back to the downwind and attempt it again. This permits maximum practice of the prescribed maneuver in the allotted time.

6. *Automatic Demonstration*. This capability permits the student, instructor or experimenter to call for the demonstration of a selected maneuver or a part thereof. "Perfect" maneuvers will be recorded and stored for this use. Playback will involve all motion cues, instrument readings, and visual scenes of the total simulator system. Recorded audio instruction synchronized with the visual display will accompany the playback when desired. Portions of the maneuver can also be selected for maximum flexibility. This capability allows standardization of maneuvers and instructional techniques. In addition, it permits students to see and then practice without an instructor present.

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7. *Knowledge of Results (KR).* Students can be provided KR on their performance in several ways. Available techniques include performance playback, CRT presentation, alpha numeric score, audio message, or any combination of these.

8. *Self-Confrontation (SC).* SC permits the student to examine his own performance through a playback of that performance using all systems including stick, throttles, and rudder. This playback can be presented in slow, real, or fast time (except motion) for demonstration and KR. Such self-observation enables the student to evaluate his behavior from a more objective position and is expected to lead to large behavior changes in short periods of time.

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II. A/F37A/T4G DESCRIPTION

The T-4G is an updated ME-1 trainer modified to accommodate a Singer SPD Electronic Perspective Transformation (EPT) visual system. The ME-1 itself is essentially a T-4 instrument trainer mounted on a two degree-of-freedom motion base.

Following is a list of major simulator components:

Modern Microelectronic Computer
T-4 Cockpit
Two DOF Motion
EPT Visual System
External Operator Station
Internal Instructor Station

The motion system moves ±5.5° pitch, ±8.5° in bank, and vertically +6″ and –4″. The visual display field of view of view is 44° x 28°, and the image is provided in full color at infinity. Image generation for the visual display is obtained from two sources: color movie film and a electronically generated horizon display. An approach, landing, and take-off movie sequence filmed at Williams AFB projected on the visual display will track student pilot control inputs. Changes in aircraft speed are achieved by changes in film speed; vertical and lateral deviations from the path of the film are produced by the EPT system. The EPT visual system will provide: normal straight-in approaches from four miles out, no flap and simulated single engine configurations; touchdown, landing roll; and take-off to 500′ above ground level (AGL).

The electronically-produced visual scene showing a horizon defined by blue sky and a cloud deck is provided for airwork; horizontal translation is not provided. Display image motion capability of 360° continuous motion in pitch, roll, or heading permits acrobatic practice in the simulator, however, the limited motion cues and field of view detract from realism.

In addition to motion and visual cues, the T-4G includes a complete nav/comm system and the capability to produce aural cues such as wind, engine sound, landing gear warning, system operations, etc.

Aids for instruction included at both operator and instructor station are the capability to freeze the simulator during a mission, and to reset to a preselected position within a matter of seconds.

Within the limits of its visual and motion systems, the T-4G will simulate T-37 flight and, since it is ground based, it may be used to provide training in areas which are avoided in the T-37 for reasons of safety. These areas are traffic pattern stalls at traffic pattern altitude, forced landing with both engines shut down and single engine procedures with one engine completely shut down.

III. FORMATION FLIGHT TRAINER (FFT) DESCRIPTION

The FFT is a fixed base, low fidelity, part task trainer specially designed to provide essential cues necessary to teach UPT pilots basic formation flight skills. The cockpit is an inexpensive mockup of a T-38 cockpit including operative rudder, stick, throttle, speedbrake, airspeed indicator, and intercom systems; all other indicators, controls, systems, etc., are omitted. An artists concept is presented in Figure A6.

An eight foot spherical screen is used and provides a 200° horizontal by 90° vertical field of view. The image projected on the screen is provided from two sources; (a) a horizon with dark sky and light earth (undercast) generated by a point light source and mounted over the student pilot's head; and (b) a picture of the T-38 model aircraft projected via a TV projector. The horizon moves in accordance with a real world picture at 30,000 feet of altitude; the aircraft image moves in accordance with the relative position of the wing aircraft.

The aircraft image is generated by a TV camera focused on a lighted T-38 model. The model is gimbal mounted on three axes. Ranging between aircraft is from three feet (from metal touching) to 8,000 feet. The first 350 feet of separation is achieved by physical travel of the camera: the remainder is achieved by computer controlled raster changes. Computer commands resulting from trainee control inputs which call for closer than three feet separation causes a red light to illuminate signaling a crash. Trainer commands, model movements, and horizon displacements are all integrated and executed by means of a Varian 620/L100 minicomputer with 8K memory (16 bit words).

The trainer has the capability to provide formation training in fingertip, crossunder, turning and straight-ahead rejoins, echelon turns, modest climbs and descents, shallow turns left or right, and combinations of these last two maneuvers.

All of these maneuvers are preprogrammed for the lead aircraft. In addition, automated demonstrations of crossunders and rejoins are available.

The instructor controls maneuver selection by use of a portable control box which is free to move about within 8 to 10 feet of the trainer.

REFERENCE

Wood, M.E., et al. *Design of the simplified formation trainer*. AFHRL-TR-72-8, AD-754 973. Williams AFB, Ariz: Flying Training Division, Air Force Human Resources Laboratory, March 1972.

IV. T-40 TRAINER DESCRIPTION

The T-40 is a modest fidelity instrument and procedures trainer using a two degree of freedom hydraulic motion system. The cockpit provides for side-by-side seating, dual contacts (wheel), and

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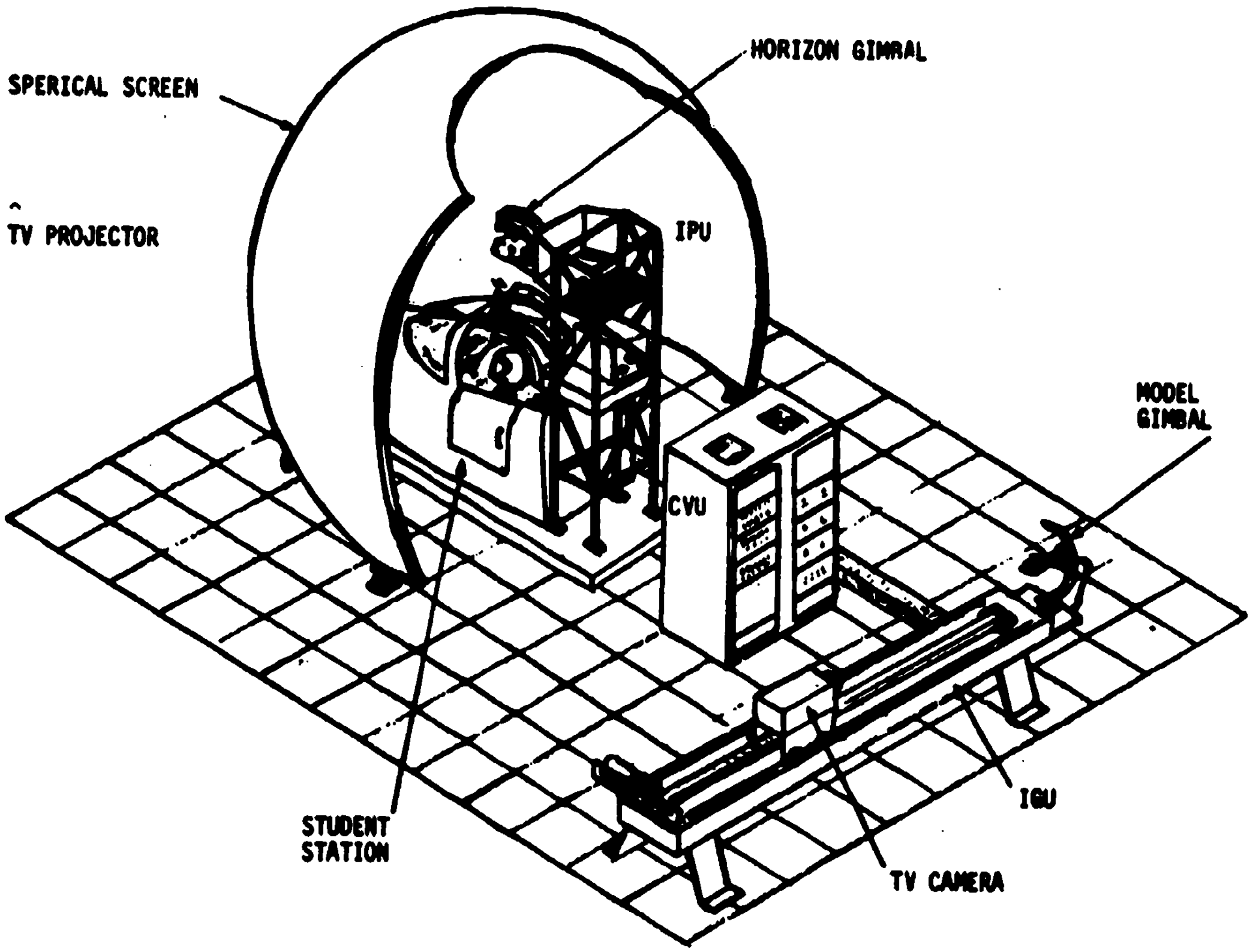

Figure A6. **Artist's concept of formation flight trainer (FFT).**

instrument similar to those installed in T-39 aircraft. (The commercial version of this trainer is called a GAT-3) A hybrid computer (i.e., digital and analog computation) is installed in the nose of the trainer and handles all computations. Space is provided in the cockpit for one or two people in addition to the pilot and co-pilot.

The device includes all types of radio equipment and VOR and OMNI instrument approach systems. System malfunctions are possible. Performance characteristics and speed ranges are close to those of T-39 aircraft. The instruments on the left side are similar to T-38 instruments and those on the right are similar to T-37 aircraft.

An external instructor or operator station is provided and includes an X Y plotter, capability for malfunction insertions, and communications monitoring and transmission facilitirs.

The trainer is capable of simulating the complete repertoire of instrument training.

V. AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM (ADACS)

The basic ADACS (Figure A7) utilizes a System Engineering Laboratory (SEL) 7200 computer and consists of: one analog to digital converter and controller (11 bits plus sign; 50KC conversion rate with programmable rate control); multiplexer to handle 128 channels of data; one data-linkage device (CPU) to provide a minimum of 16K memory and a 131K fixed head disc; a card reader; a teletypewriter input/output device; and three magnetic tape units. The central processing unit has a full cycle time of less than 900 nanoseconds.

The operating system is a multiprogramming system with an assembler, FORTRAN IV compiler, a BASIC compiler, a conversational FORTRAN IV compiler, a math library, a debug package, and a symbolic editor. This system software also generates magnetic tape Cal Comp Plotter code for off-line processing on the SEL 8600 plotting system. A real-time clock is provided. The ADACS system is interfaced with ASUPT/CIG system and line printer.

ADACS samples data parameters from two T-40 trainers, one FFT, and the T-4G. These data are sampled at 20 times per second. The parameters for the T-4G and T-40s include:

1. ∠ of attack
2. Altitude
3. Stk Pitch
4. Rate of Climb
5. Vert Accel
6. Bank ∠
7. SIN Heading
8. COS Heading
9. Rate of Turn
10. X-A/C Posit
11. Y-A/C Posit
12. Aileron Posit
13. Rudder Posit
14. Elevator Posit
15. L. Throt Posit
16. R. Throt Posit
17. L. Eng Thrust
18. R. Eng Thrust
19. Pitch ∠
20. SLIP ∠
21. X GS
22. Y GS
23. SIN Wind
24. COS Wind
25. CD Bar
26. Glide Slope Dev Bar
27. True Vel
28. Mach #
29. IAS

The parameters to be recorded for the FFT are:

1. Range Rate
2. Alt Dif
3. Head Diff
4. Range
5. Stick Pitch
6. Stick Roll
7. Rudder
8. Thrust Sets
9. Speed brake
10. Trim input
11. ∠ of bank
12. Lat Displ
13. Long Displ
14. Event Mach
15. Pitch ∠
16. ∠ of attack
17. Slip ∠
18. Vert Accel
19. A/S

The ADACS will permit research in the areas of developing techniques for recording meaningful performance measures and proficiency measurement using objective data. When developed, these techniques will permit research on training methods and equipment in which differences in trainee performance can be readily and reliably assessed.

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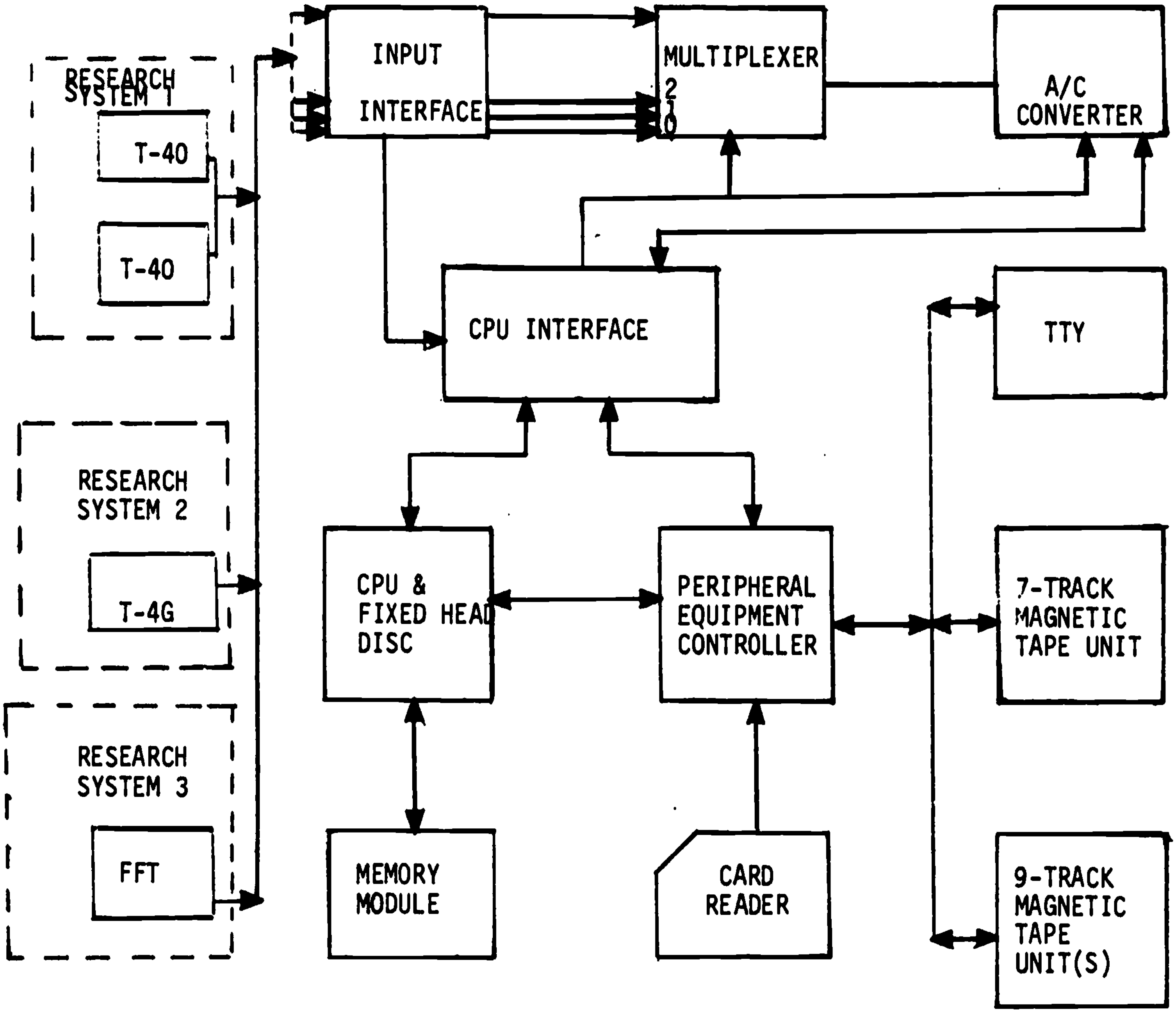

Figure A7. **Automatic data acquisition and control system schematic.**

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APPENDIX B: TRAINING PROBLEMS TO BE INVESTIGATED USING ASUPT AND OTHER RESEARCH DEVICES

There are two broad categories of training research which may be investigated with ASUPT and the other research devices at AFHRL/FT. These are: (a) trainer utilization, and (b) training equipment characteristics. The category of trainer utilization involves questions as to how the syllabus may be structured to best use the trainer. This involves research to determine the best training strategy for the student in the employment of the trainer features and the opportunity it provides for application of training principles. The category of training equipment characteristics encompasses the physical aspects of the trainer, both hardware and software and includes its motion capabilities, its visual attachment, and, in general, its capability for providing relevant stimuli to the trainee and the means for making appropriate responses.

The following list of items constitute areas of research which have been identified as those which are pressing in terms of importance for making pilot training more effective. The research which would provide definitive data or information pertaining to these questions would be highly useful in making decisions as to the direction training should go and the type of training equipment that should be used.

In the paragraphs to follow a reasonably concise definition or description of a number of research areas falling under the major categories are given so that they may be reviewed and priorities assigned in terms of their order of importance in being taken up in a training research program. In many of the research areas, it has been possible to shred out more detailed problems. When this has been possible it is intended that priorities will be assigned to these sub-categories within the major areas in *addition to* and *independent of* the assignment of priorities to the major categories.

Contextual Training

This area of concern is with training taking place within the context of operational tasks and applications. For example, basic instrument maneuvers such as 30° bank turns could be taught in the context of an overall maneuver such as an instrument approach. This is basically the part versus whole training problem. That is, should tasks such as 30° bank turns be practiced separately and uniquely or within the context of a broader maneuver? The experimental question may be stated as being "what is the proper mix of practice on small unit tasks and overall broad maneuvers such as an instrument approach or a holding pattern?"

Sequencing of Training Tasks, Maneuvers and Phases

This area is concerned with the ordering of the tasks, maneuvers and phases such that optimum transfer from fundamental skills and knowledges to higher difficulty is obtained and results in the most efficient progression through the syllabus. Specific research questions are as follows:

a. Should instrument flight training precede or follow contact flight training?

b. At a more detailed level than in (a) above, should instrument flight training be integrated into contact such that it is taken up concurrently in learning to perform specific maneuvers; e.g., an approach to a landing?

c. Investigations which separate the psychomotor aspects of the learning tasks from the perceptual aspects and develop the skills in the two through more relatively simple training devices before training in combination in more complex devices such as the full scale simulator of the aircraft.

Extension of the Training Syllabus

Emphasis on training in tasks and maneuvers which are avoided in the aircraft for reasons of safety. Also, training in tasks which require controlling the aircraft to the limits of its performance and structural integrity; e.g., control at the critical airspeed limits.

Performance Measurement

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Within this category there are five identifiable, independent sub-categories as follows:

a. *Check-ride Performance* – extent to which check or criterion rides in the simulator may be substituted for those in the aircraft.

b. *Diagnostic Measures* – measures of specific items at a particular time during a practice session or learning process which are designed to identify and isolate specific sources of difficulty being experienced by the trainee in his acquisition of the criterion skills or knowledge.

c. *Control Output Measures* – identification of the parameters to be sampled and recorded; e.g., lateral stick input, and the methods for summarizing or transforming them into the most meaningful and valid form; e.g., spectral density function or frequency analyses.

d. *System Output Measures* – identification of those parameters to be sampled and recorded by maneuver or task; e.g., altitude or airspeed, and the methods for summarizing them into the most meaningful and valid form; e.g., integrated absolute error, RMS, etc.

e. *Observer Records of Performance* – investigation of the methods and techniques, whereby the instructor pilot or other observer may record performance through watching the standard instruments on the aircraft panel, the contact world scene and the actions of the trainee.

f. *Observer Opinion Data* – investigation of the methods and techniques, whereby an observer such as an instructor pilot, test pilot, design engineer or behavioral scientist may record or express his judgments or opinions in a useful and reliable manner.

g. Determination of the relationship between specific and detailed diagnostic and criterion measures obtainable in the simulator and those measures possible of being obtained by the instructor pilot observing the trainee performance in the aircraft.

Performance Feedback

This area is concerned with the provision of knowledge of results or feedback to the student about his performance. Usually knowledge of results are given relevant to some criterion or standard. This area of research can be divided into sub-categories as follows:

a. *Instructor Feedback* – information given to the student as to the quality of his performance by the instructor based upon information he obtains either from his observations of the student's activities, panel instruments, contact scene or, in the case of the simulator, specific performance measures of both criterion and diagnostic nature.

b. *Visual Continuous (relative to criterion performance)* – visual feedback such as red and green lights to indicate performance relative to limits. An alternate form of this feedback might be a numerical display indicating percent of criterion attainment; e.g., when the display reads 100 the trainee has attained criterion performance.

c. *Visual Continuous (progress-regress)* – feedback to a student which indicates to him that he is progressing; i.e., continuing to improve, or is regressing. This can be in the form of red and green lights or, in the case of numerical values, showing percent of attainment of criteria. An increasing value shows improvement while a decreasing value shows retrogression.

d. *Visual Intermittent* – in this category of research concern is with the provision of feedback to the student at the end of a trail or run with a summary of performance provided to him by an alpha-numeric display on a CRT.

e. *Auditory Continuous (relation to criterion performance)* – here the concern is with the feedback of information to the trainee continuously through a word or phrase generator which informs the trainee whether or not he is performing within limits or to criterion.

f. *Auditory Continuous (Progress-regress)* – verbal information feedback to the trainee which informs him that he is either continuing to improve or is regressing.

g. *Auditory Intermittent* – summary at the end of the trial which informs the trainee of his overall performance with respect to the criterion.

h. *Auditory Continuous Diagnostic* – feedback through the auditory channel which deals selectively with the tasks being performed by the trainee and points out the parameters of the task which he is not performing to criterion.

i. *Self-Confrontation* – playback of a trainee's performance during a practice trial through activation of the instruments and controls of the simulator. Playback may be either in slow, real or fast time.

j. *Graphics* – the continuous visual display of the two-dimensional picture of progress through a maneuver; e.g., the actual ground track being accomplished displayed on a CRT and compared to desired ground track.

Training Management

This category may be broken down into two major areas, one of which deals with the adaptation of the syllabus, its tasks and maneuvers to the progress of the student and the other which deals with the adaptation of the characteristics of the training device or media on the basis of his progress. The first has been called individualized instruction, the term which we will use here, and the second has been termed machine adaptive training. Both may be under the control of the instructor in what may be termed a manual mode or they may be highly automatized as is possible with a system such as ASUPT and the additional capabilities provided by ADACS.

a. *Individualized Instruction* – determination and description of the specific tasks to be taken up in the syllabus, specification of criterion performance either normative or administrative, and progression of the student through the syllabus on a performance to criterion basis with provisions for branching back for rehearsal of tasks.

b. *Machine Adaptive Training* – adjustment of the characteristics of the training device or media such that the trainee progresses to criterion performance at his own individual pace based upon measurement of his progress. Adjustment of the machine characteristics is customarily such that the trainee's task is easy during his initial practice trials and is adjusted to become difficult based upon his progress until he reaches criterion performance.

Out of the Window Cue Simulation

This category covers what is often referred to as the visual system in aircraft simulators. It is concerned with presenting the real world visual scene outside the aircraft to the trainee. It may be divided into sub-categories as follows:

a. *Field-of-View* – this category concerns the solid visual angle to be covered by the display. Measured from a forward line of regard, what vertical and horizontal visual angles should be covered by the display?

b. *Color* – this item is concerned with whether the visual display should be achromatic or contain some level of approximation to real world color.

c. *Collimated Imagery* – this item is concerned with whether the image being displayed to the trainee should be collimated and, thus, appear at virtual infinity as opposed to appearing on a surface a short distance from the trainee.

d. *Content of the Display* – this item covers the study of what objects, points, lines and so forth should appear in the display as sources of information for the trainee in carrying out his aircraft control tasks.

e. *Quality of the Display* – this item concerns those aspects of the display such as brightness, resolution, sharpness, contrast and distortion of the displayed image which have to do with its legibility.

Motion Cue Simulation

This area of research may be subdivided into what may be termed the on-set or true motion cues and their washback, and those cues which are sustained by means of pressures on the trainee's body. The latter are implemented by pneumatically driven elements in the simulator seat and through the gravitational

alignment cue provided by tilting the motion platform. Motion cues are provided by the six degrees of freedom of movement of the platform and to some extent by the actuation of the pneumatically driven elements in the seat pan of the trainee's seat. The individual research items which may be broken out of these two major categories are as follows:

a. Contribution of the individual or combined degrees of freedom of motion of the platform to training of the undergraduate pilot trainee.

b. Contribution of the individual or combined motions of the degrees of freedom of motion of the platform to the proficiency measurement of the trainee; e.g., periodic or final checks.

c. Contribution of the individual or combined degrees of freedom of motion to the rention of skills by the trainee at various levels of training.

d. Contribution of the gravity alignment cue to training. This cue comes from tilting the platform such that normal gravity is used as a substitute for the acceleration when the aircraft is accelerating for take-off or decelerating during landings.

e. Determination of the degree to which the seat pan pneumatically driven elements may provide the pitch and roll cues available to the trainee during various training tasks and maneuvers.

f. Determination of the contribution to training of the sustained pressures provided by the pneumatically driven elements of the student's seat.

g. Determination of the optimum frequency response in pitch, roll and yaw of the platform for training cost effectiveness; i.e., what fidelity of motion is optimum for training.

h. Determination of the optimum program for introduction and washback of linear movement of the motion platform for training cost effectiveness.

Disorientation Training

This category is concerned with the research into training to recognize and cope with disorientation during flight. It investigates the requirements for a simulator to induce disorientation and the methods and techniques for training in recognizing and coping with the problem.

Instructional Aids

This area of research is concerned with the *methods, procedures* and *devices* which may be used in connection with a simulator and within a training system to bring about more effective training. The list of items which may be broken out under this category are as follows:

a. *Maneuver Demonstration* – this refers to the capability of the device for "playing through" the maneuver in automated mode for the purpose of demonstrating it to the student. Such demonstration may include visual modeling as described in b. as follows.

b. *Visual Modeling* – This item refers to the process of exhibiting to the student on a visual display the progress through a maneuver as a developing two-dimensional spatial pattern as he progresses through the maneuver. For example, while the student is performing a holding pattern using information derived from the instruments on the aircraft panel a CRT display may graph for him his ground path relative to the desired holding pattern. These aids may be withdrawn as trainee learning progresses. This capability may also be considered as a form of feedback and is listed as such under item Performance Feedback, paragraph j.

c. *Instructional Cues* – in this item of research use is made of the instructional cues derived from task analyses in that the instructional cues for each task or maneuver are singled out and made explicit for the trainee. Instructional cues are defined as the stimuli which provide the information, often in the form of a rule or a set or procedures, which enables the learner to perform the behavior described in a performance objective. It is the minimal informational stimulus, either audible, visual or tactual, which must be supplied to the learner in order to enable him to make the desired response. The emphasis in this area of research would be the pointing out or making explicit to the learner what instructional cues are involved in performing the task. This may be carried out through use of the visual and/or auditory display capabilities of the ASUPT or use of other less complex audio and/or video devices.

d. *Part-Task Trainers* – research using much less complex devices than the ASUPT to train in parts or aspects of a task prior to ASUPT training. Such devices might include full scale panel illustrations or pictures, mock-ups, procedures, trainers and audio-visual devices for training in procedural, perceptual and cognitive type tasks.

e. *Prompting and Cuing* – prompts are signals which indicate that the time has come for a specific action to occur and directs the student to perform that particular action. Cuing is similar to prompting but usually refers to a simple signal that indicates time to act. Thus, a cue is less directive than a prompt.

Aircraft Dynamics Simulation

This area of research deals with the degree to which the equations describing the motions of the simulated aircraft should be represented and implemented in the simulator. It is directed essentially toward the degree to which these equations might be simplified in their implementation in the simulator with possible reduction in required computer speed and/or capacity.

Peer Training

Research in which the trainee's peers may observe and work with him while he practices or engages in the solution of problems. This category may be subdivided as follows:

a. Peer training in which the fellow trainee engages in helping the trainee solve problems or improve his skills through discussion, suggestion and critique of his performance.

b. Peer training in which the fellow trainee acts as a passive observer (sometimes called observer training) and notes the performance of the trainee being observed, the types of errors which develop, and can mentally rehearse his own techniques and approach to solving the problem or acquiring the skill.

Instructor Training

This area of research is concerned with developing information which may be used to make the instructor more effective in his guidance and management of the student's progress through the training curriculum. It may be subdivided into the following categories:

a. *Performance Evaluation* – this area includes research in the training of the instructor in the evaluation of the performance of the trainee in the simulator and in the aircraft and the relationship between the performance measures obtained in each of these training situations. A greater array of performance evaluation means is available to the instructor in the simulator than in the aircraft. Instructor training in the use of diagnostic and criterion proficiency measurements in the simulator is the concern of this research area. Of particular concern is the interpretation and translation of the more detailed measures taken in the simulator into instructional guidance and performance evaluation in the aircraft.

b. Use of the diagnostic information provided by the simulator performance measures for either extemporaneous or standardized instructions and guidance to the trainee.

c. *Degree of Instructor Participation* – this research item refers to the degree to which the instructor actively participates in the ongoing practice of the trainee. On the one hand the instructor may demonstrate the task, talk the student through maneuvers and provide evaluative and directive information throughout the course of the student's practice. On the other, he may adopt a passive role in which he provides information only when questioned by the trainee and injects himself into the training practice only to assure safety.

d. *Degree of Instructor Task Automation* – this item refers to the analysis of the instructor's task and the allocation of certain of these to automatic execution by the training simulator. The types of functions and tasks that fall within this category are briefings, demonstrations, performance evaluation and assignment of training tasks.

e. *Instructor Motivation* – investigation of the incentives and awards which may be used to increase instructor interest and enthusiasm.

f. *Instructor Standardization* – research concerned with training and measuring the instructor's ability such that he maintains his effectiveness at a defined and established level.

Trainee Motivation

This area of research involves investigation of the role which incentives may plan in bringing about more effective training. These may involve competition among trainees or other incentives and awards for accomplishment.

Relationship of Trainee Traits to Methods of Instruction

This area of research is concerned with the investigation of relationships between methods of presenting the training materials and certain measurable traits of the individual. For example, measurable traits such as visual field dependency or manifest anxiety may be hypothesized to be determiners of the method or mode of instructions to be used for a given trainee.

Auditory Cue Simulation

This area of research is concerned with the auditory spectra emanating from the aircraft which may be important as an information source, as a means of adding realism to the training situation or as noise which interferes with obtaining information or may otherwise be detrimental to performance.

Kinesthetic Due (Control Feel) Simulation

This area of research deals with the investigation of the degree to which the control forces and displacements in the aircraft being simulated should be represented in the simulator.